EFFECTS OF ARTIFICIAL ACID PRECIPITATION AND LIMING ON FOREST MICROARTHROPODS

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ВЛИЯНИЕ ИСКУССТВЕННЫХ КИСЛЫХ ОСАДКОВ И ИЗВЕСТКОВАНИЯ НА ЛЕСНЫХ МИКРОАРТРОПОД

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Introduction

Acid rain is a growing problem both in Europe and North America /3,1, 12/. In Norway, extensive studies have been made on the effects on freshwater and forest ecosystems /13/. Soil microarthropods have been included in these investigations. The present paper sums up the main results and discusses possible explanations of observed relationships between microarthropods and soil pH.

Material and Methods

The investigations have followed three different approaches:

1. Colonisation experiment. Microarthropods were allowed to colonise and reproduce in soil samples which had been adjusted to different pH levels /8/.

2. Field Experiments with Artificial Acid Rain and Liming. In coniferous forest with podzol soil (Typic Udipsamment), experimental plots were either limed or treated with artificial rain of pH 6 (control), 4, 3, 2.5 or 2. Effects on Acari have been described earlier /9,5/. Effects of artificial acid rain on microarthropods were also studied in decomposing birch leaves, both in the field and in a greenhouse experiment /10/.

3. The Distribution of Microarthropod Species in Natural Soils of Different pH. This was considered to be an important control of the experimental results. If a general relationship exists between soil pH and the abundance of a given species, this should also be reflected under natural field conditions /8,6/.

Results

The results from the two first approaches are summarized in the Table. In the field experiments, most effects of acidification were noted in the two strongest treatments, with artificial acid rain of pH 2.5 and 2. For comparison, the table includes the results from a Finnish liming experiment /4/ and a Swedish acidification experiment /2/.

The following conclusions can be drawn from the Table.

1) Changes in soil pH have affected the abundance of a large number of species, both among Collembola and Acari. 2) Within both groups, several different reaction patterns appeared. The total picture thus becomes very complex. The results illustrate well the necessity of identifying the animals to species level. 3) Results from independent experiments did in most cases support each other for a given species. 4) some species were especial-

Significant reactions (P ≦ 0.05) among microarthropods to artificial liming and acidification

Microarthropod species	Effect of liming							Effect of acidification									
	/8/			/9,5/			/4/	/8/			/9,5/			/10/			/2/
	Colonisation experiment			Field experiment				Colonisation experiment			Field experiment			Birch leaves			
														Field	Green-house		
	Raw humus	Poor mull	Rich mull	A-1 1975	A-1 1977	A-3 1978		Raw humus	Poor mull	Rich mull	A-2 1975	A-2 1977	A-3 1978		Early de-comp.	Late de-comp.	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1. Increased abundance by acidification and/or reduced abundance by liming																	
ACARI																	
Oribatei																	
Tectocepheus velatus (ad.+ +juv.)	-					-	-	+	+				+	+	+	+	+
Nothrus silvestris (ad.+juv.)	-		(-)	-	-	-	-	+	+	(+)							
Steganacarus sp. (ad.)															+	+	
Nanhermannia sp. (ad.)				-													
Ceratozetes thienemanni (ad.)	-																
C.gracilis (ad.)							-										
Oribatei, total						-	-	+			+		+	+			
Astigmata																	
Schwiebea gen. nova Vitzthum (ad.+juv.)			(-)					+	+	(+)					+		
Astigmata, total								+	+	+					+		
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Mesostigmata																	
Eviphis ostrinus (ad.+juv.)															+		
Leioseius bicolor (ad.)														+			
COLLEMBOLA																	
Mesaphorura yosii					-	-	-	+			+	+					
Anurida pygmaea	(-)					-	-	(+)									+
Willemia anophthalma				-							+		+				
Karlstejnia norvegica													+				
Tullbergia krausbaueri s.l.							-										+
Folsomia sensibilis						-											
F.fimetarioides							-										
Anurophorus septentrionalis						-											
Neanura muscorum														+			
2. Reduced abundance by acidification and/or increased abundance by liming																	
ACARI																	
Oribatei																	
Chamobates sp. (ad.)															-		
Hemileius initialis (ad.)															-		
Porobelba spinosa (ad.+juv.)																	
Steganacarus magnus (ad.)	+																
Mesostigmata																	
Pergamasus lapponicus (ad.)									-								
Veigaia nemorensis (ad.+juv.)	+															-	
Trachytes sp. (ad.+juv.)					+								-		-		-
Uropodina, total													-				

T a b l e (end)

1	2	3	4	5	6	7	8	9	10	11	12	13	1	15	16	17	18
Prostigmata																	
Prostigmata, total													-				
COLLEMBOLA																	
Isotoma notabilis	(+)						+	(-)		-			-	-	-	-	
Isotomiella minor			(+)							(-)			-		-	-	
Lepidocyrtus cyaneus												-		-		-	
Onychiurus absoloni							+						-				
Mesaphorura tenuisensillata		(+)							(-)								
Neelus minimus															-		
PROTURA																	
Protura, total	(+)					+		(-)									
3. Reduced abundance recorded both by acidification and liming																	
ACARI																	
Mesostigmata																	
Parazercon sarekensis (ad.+large juv.)						-						-	-				
COLLEMBOLA																	
Onychiurus armatus s.l.			-			-							-		-		
4. Various reactions																	
ACARI																	
Oribatei																	
Brachychochthonius zelawaiensis (ad.+juv.)	-				-	-			+					+	-		

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Brachychthoniidae, total			-			-	-				+			+	-		
Oppiella nova (ad.)	-							+							-	+	
Oppia obsoleta (ad.)			(-)							(+)							-
Oppia neerlandica (ad.)							-										
Suctobelba sp. (ad.)						-	-		-	+			-				
Mesostigmata																	
Prozercon kochi (ad.+large juv.)	(-)							(+)								-	
Gamasina	(-)					-		(+)	-			-	-			-	
Mesostigmata, total	(-)					-		(+)	-			-	-			-	
Acari, total						-		+				+	-		+		
COLLEMBOLA																	
Friesea mirabilis	(+)							(-)					+				
Collembola, total				-		-	-				+		-		-	-	

N o t e: The symbols (+) or (-) indicate increased or decreased abundance compared to control. Symbols in brackets mean that the difference is significant only when limed and acidified samples are compared. If not otherwise indicated, abundance data from field experiments are from the upper 6 cm (O+E) and the effects are related to the strongest treatment.

ly sensitive to changes in soil acidity and showed significant reactions in several experiments. A number of species reacted in only one or a few expèriments, while certain microarthropods (not included in the table)were never significantly affected. 5) The reactions can be classified into four categories: a) abundance increased by acidification and/or reduced by liming; b) abundance reduced by acidification and/or increased by liming ; c) abundance reduced by both acidification and liming; d) various reactions (inconsistent reactions noted to either liming or acidification).6)Most species belonged to the two first categories. No species increased their abundance in both limed and acidified soil. 7) While a number of both Collembola and Acari species increased their abundance in certain acidification experiments, liming very rarely gave increased abundance of a species or group. A large number of microarthropod species reduced their abundance in limed soil. 8) When significant reactions to liming were noted in Collembola or Acari as a whole, the result was reduced abundance. Acidification could either reduce or increase the abundance of these groups. Significant reactions in Oribatei as a whole always implied reduced abundance in limed soil and increased abundance in acidified soil.

The Finnish and Swedish results conform well with the present data. The Swedish "Tullbergia krausbaueri" may prove to be identical with Mesaphorura yosii.

The many cases of reduced abundance in the greenhouse experiment /10/are probably related to the frequent application of a strongly acidic solution (pH 2). For several species, the reactions may have had the character of "shock-effects". The following species of category four in Table 1 are therefore closely related to the first category: Brachychochthonius zelawaiensis, total Brachychthoniidae, and Oppiella nova. Most remaining taxa in the last category consist of species groups, which may explain the different reactions in different experiments.

As noted in pt. 4 above, certain species seem to be especially sensitive to changes in soil acidity. Their significant reactions noted in the Table were often supported by non-significant trends. The Collembolan Isotoma notabilis was characteristic by being negatively affected by acidification, while liming might give increased abundance. This species was also most abundant in natural soils of rather high pH /8/. Conversely, several microarthropods which were negatively affected by liming and increased their abundance in acidified soil were most abundant in naturally very acid soils /8,6/. Typical species in this category were the three Oribatei Tectocepheus velatus, Nothrus silvestris, and Brachychochthonius zelawaiensis,the Astigmate Schwiebea cf. nova, and the three Collembolans Mesaphorura yosii, Anurida pygmaea, and Willemia anophthalma. Thus, for several microarthropods, there seems to be general relationships between abundance and soil pH.

Discussion

A number of possible explanations for these reactions have been discussed by Hågvar (1984c). At the present level of knowledge, the following hypothesis is considered to be the best: competition is an important population-regulating factor for microarthropods, and at different soil pH levels,

different species are favoured in the competition process. The hypothesis is based mainly on two observations: 1. When "acidophilic" species are kept in monoculture in soils of different pH, population growth is not highest in the acidified soil. The "typical" reaction to soil pH evidently depends upon the presence of other soil animals. 2. When naturally acid soil is acidified further, the dominant species become still more dominant. The success of these species in a community seems to be generally related to soil pH.

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Discussion

Zettel J.: What was the amount of artificial acid rain added in comparison to the amount of natural precipitation?

Hågvar S.: We added 50 mm of artificial acid rain each month from May to September. In addition comes the natural rain of approximately 80 mm per month.

Štebaeva S.K.: What effect have the artificial acid rain on the epigeic and litter-dwelling forms of Collembola?

Hågvar S.: The surface- and litter-dwelling species were so scarce that we did not receive liable data from them. But one species which lives rather high up in the raw humus layer, Isotoma notabilis, was reduced in abundance in acidified soil.